

Structural Health Monitoring of Composite Bridges by Integrating Model-based and Data-driven Methods

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Thesis submitted in fulfilment of the requirements for
the degree of

Doctor of Philosophy

under the supervision of Professor Jianchun Li

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January 2021

Certificate of Original Authorship

I, Faraz Sadeghi declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Civil and Environmental Engineering, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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To My Beloved Parents

Acknowledgment

First and foremost, I would like to express a hearty sense of gratitude to my beloved mother and father, to whom I owe my life for their endless love, encouragement, support, and blessings. I am deeply grateful to you for being by my side whenever needed.

This thesis would not have been possible without the support and advice from my supervisory panel. I would like to express my sincere appreciation to my supervisor, Professor Jianchun Li, whose encouragement, guidance, and continuous support enabled me to pursue my PhD successfully. I am thankful for all the fantastic and incredible discussions we had for developing a deep understanding of the project.

I would like to express my great appreciation to my co-supervisor, Associate Professor Xinqun Zhu, who had always been generous with his contributions and ideas, and helped me conduct my project innovative and be productive. Thank you for your encouragement, mentorship, and patience.

My sincere thanks also go to the University of Technology Sydney for providing excellent research and social environment, scholarships, financial supports, facilities, and funding resources that made this thesis possible. I thank the supportive administration and technical staff at the Faculty of Engineering and Information Technology, School of Civil and Environmental Engineering, and UTS TechLab.

Finally, I would like to thank my beloved brother, who has always supported me, and his encouragement and belief in me were worth more than words.

Publications

- Sadeghi F, Li J, Zhu X. A steel-concrete composite beam element for structural damage identification. *International Journal of Structural Stability and Dynamics*. 2020;20:2042015.
- Sadeghi F, Zhu X, Li J. Damage analysis of steel-concrete composite beams under static loads. *Proceedings of the International Conference on Structural Dynamic, EURODYN2020*. p. 1053-62.
- Sadeghi F, Yu Y, Li J, Zhu X. Damage identification of composite structures based on modal strain energy changes through general regression neural network. *Journal of Engineering Structures* (2021) - Under review
- Sadeghi F, Li J, Zhu X, Rashidi M. A novel slip sensory system for interfacial condition monitoring of steel-concrete composite bridges. *Journal of Remote Sensing* (2021) - Under review

Table of Contents

Certificate of Original Authorship	ii
Dedication	iii
Acknowledgment	iv
Publications	v
Table of Contents	vi
List of Figures	ix
List of Tables.....	xiii
Abstract	xiv
Chapter 1 Introduction	1
1.1 Background.....	1
1.2 Research objectives.....	3
1.3 Contributions to knowledge.....	4
1.4 Organisation of the thesis	6
Chapter 2 Literature review	8
2.1 Overview.....	8
2.2 Steel-concrete composite structural system.....	10
2.3 SHM of composite bridges	13
2.3.1 Static-based damage identification methods.....	16
2.3.2 Dynamic-based damage identification methods	18
2.4 SHM using data-driven methods	28
2.4.1 Application of artificial intelligence in SHM of bridges.....	29
2.4.2 Machine learning methods in SHM	31
2.5 Application of displacement sensors in SHM.....	37
2.6 Research summary and gaps.....	39

Chapter 3	Structural damage detection of composite structures with limited static measurements.....	41
3.1	Overview.....	41
3.2	Analytical procedure.....	42
3.2.1	Basic formulations.....	42
3.2.2	Stiffness matrix of the steel-concrete composite element.....	45
3.2.3	Elemental damage indicators	48
3.3	Structural damage identification using static measurements	51
3.4	Results and discussion	55
3.4.1	Model validation	55
3.4.2	Convergence analysis	60
3.4.3	Parametric study	61
3.4.4	Verification of the proposed method.....	63
3.5	Suggestion for practical application.....	76
3.6	Concluding remarks	77
Chapter 4	Structural damage detection of composite structures with dynamic measurements.....	79
4.1	Overview.....	79
4.2	Analytical background.....	80
4.2.1	Basic assumptions	80
4.2.2	Elemental stiffness and mass matrices	82
4.3	Structural damage index	87
4.4	Modal parameters	89
4.5	Experimental model.....	91
4.6	Numerical model.....	95
4.7	Results and discussion	98
4.7.1	Structural damage identification using eigenvalue changes ..	98
4.7.2	Damage identification based on MSEC and machine learning	103
4.7.3	Damage identification	108
4.8	Concluding remarks	112

Chapter 5	Interface condition monitoring of composite beams using interlayer slip measurements	114
5.1	Overview	114
5.2	Interface monitoring system	115
5.2.1	Slip sensory system	115
5.2.2	Sensor calibration	117
5.3	Experimental setup	121
5.3.1	The bridge model	121
5.3.2	Interface monitoring system	123
5.3.3	Experimental procedure	124
5.4	Experimental results and discussion	125
5.4.1	Inherent Interlayer slip	125
5.4.2	Case 1: Removing one bolt connector	127
5.4.3	Case 2: Removing the second and fifth bolts	131
5.5	Concluding remarks	135
Chapter 6	Conclusions and recommendations	137
6.1	Conclusions	137
6.2	Recommendations	141
	Bibliography	142

List of Figures

Figure 2.1 Cross-section view of a typical SCC beam	11
Figure 2.2 Schematic expression of the FT in time and frequency domain.....	20
Figure 2.3 Classification of decision boundaries	30
Figure 3.1 (a) Diagram and (b) Kinematic of two-layer composite beam element; c and s denote concrete and steel layers, respectively.....	43
Figure 3.2 Nodal displacements of a steel-concrete composite element with 10 DOFs.	45
Figure 3.3 Displacements along the beam obtained from FE modeling in MATLAB (FE-M), ABAQUS (FE-A), and experimental testing (Ex-S).....	57
Figure 3.4 The experimental model (a) SCC specimen and (b) top plan view of the specimen showing the shear connector's alignments (length in mm)	58
Figure 3.5 The FE model of the SCC composite beam; displacements along the beam subjected to mid-span point load	59
Figure 3.6 Convergence analysis (a) the maximum displacement and (b) the maximum strain in terms of number of FEs.....	61
Figure 3.7 The changes of maximum (a) displacements and (b) strains of the beam with 24 FEs due to reductions in stiffness (from 0% to 90%) in Elements 4 for single damage (cases 1, 2 and 3), double damage (cases 4 and 5), and triple damage (case 6)	63
Figure 3.8 Schematic of the damage cases introduced for different elements; red color denotes damage on the concrete (top), bonding (middle), and steel (bottom); each FE element number stands in the circle on top.....	64
Figure 3.9 The damage indices identified for the concrete slab from the displacement measurements in terms of (a) the noise level and (b) different load locations	67
Figure 3.10 The damage indices identified for the steel girder from the displacement measurements in terms of (a) the noise level and (b) different load locations	68

Figure 3.11 The damage indices identified for the bonding from the displacement measurements in terms of (a) the noise level and (b) different load locations	70
Figure 3.12 The damage indices identified for the bonding from the strain measurements in terms of noise levels.....	71
Figure 3.13 The damage indices identified for the concrete slab and steel girder from the displacement measurements in terms of (a) two distributed elements and (b) two grouped elements	72
Figure 3.14 The damage indices identified for the concrete slab, steel girder, and bonding from the displacement measurements in terms of different number of measurements.....	74
Figure 3.15 The damage indices identified for the concrete slab, steel girder and bonding from the strain measurements in terms of different number of measurements.	75
Figure 3.16 The damage indices identified for the concrete slab, steel girder, and bonding from the strain measurements in terms of different numbers of measurements	76
Figure 4.1 (a) Kinematic and (b) diagram of two-layer composite with longitudinal slip and vertical uplift; c and s denote concrete and steel layers, respectively.....	82
Figure 4.2 Nodal displacements of an SCC element with 14 DOFs.....	83
Figure 4.3 Accelerometers, shear connectors and impact hammer locations	91
Figure 4.4 Experimental model built in the laboratory	93
Figure 4.5 Modal testing of composite beam: (a) impact hammer load, and (b) acceleration-time and (c) and FRFs obtained at 9 points (P-1 to P-9).....	94
Figure 4.6 Bending mode shapes (first four) of the beam obtained from Experimental testing (ExM) and FE model (FEM)	97
Figure 4.7 Identified results of 0.3 (30% stiffness reduction) damage at the interface of Element 1	99
Figure 4.8 Identified results of 0.7 (70% stiffness reduction) damage at the interface of Element 1	100

Figure 4.9 Identified results of 0.7 (70% stiffness reduction) damage at the steel and interface of Element 1	101
Figure 4.10 Identified results of 0.7 (70% stiffness reduction) damage at the concrete and interface of Element 1	101
Figure 4.11 Identified results of 0.3 (30% stiffness reduction) damage at concrete, steel, and interface of Element 1	102
Figure 4.12 Identified results of 0.7 (70% stiffness reduction) damage at concrete, steel and interface of Element 1	103
Figure 4.13 Configuration of network model for damage identification of composite beam	105
Figure 4.14 PCA results of MSECRs.....	107
Figure 4.15 Algorithm flowchart for structural damage identification.....	108
Figure 4.16 Identification results of single concrete damage of Element 1	109
Figure 4.17 Identification results of single concrete damage of Element 4.....	110
Figure 4.18 Identification results of single steel damage at Element 9	110
Figure 4.19 Identification results of single concrete-steel interface damage at Element 18.....	111
Figure 4.20 Identification results of double damage case.....	112
Figure 4.21 Identification results of triple damage case	112
Figure 5.1 Sensor film and (b) sensor system	116
Figure 5.2 (a) 3D printed wiper, (b) the sensor installation on the SCC beam, and (c) the sensors connected to the National Instruments data acquisition system.....	117
Figure 5.3 Slip-sensor calibration system	118
Figure 5.4 Calibration of seven sensors in terms of relative displacement (slip) and voltage; S1 to S7 are measured, data and R1to R7 denote calibration coefficients for sensors numbers 1 to 7	120
Figure 5.5 The drift in calibrations of 7 sensors (D1 to D7) at 5 points	121

Figure 5.6 (a) plan view and dimensions, (b) the bridge after construction, (c) covers embedded into the concrete slab in main span for the removable shear connectors, (d) reinforcement alignment and (e) discontinuous slabs.....	123
Figure 5.7 Alignments of slip sensors on the bridge.....	124
Figure 5.8 (1) first load 375kg, (2) second load 740kg and (3) third load 1100kg.....	126
Figure 5.9 The interlayer slip of composite beam without damage under loading.....	127
Figure 5.10 Second bolts are removed to define single damage.....	128
Figure 5.11 The interlayer slip of composite beam for single damage (second bolt from right-hand side is removed).....	129
Figure 5.12 Structural damage detection for single damage in terms of (a) first load increment, (b) second load increment, and (c) third load increment	131
Figure 5.13 Second and fifth bolts are removed to define double damage.....	132
Figure 5.14 The interlayer slip of composite beam for double damage (second and fifth bolts from the right-hand side are removed).....	133
Figure 5.15 Structural damage detection for double damage in terms of (a) first load increment, (b) second load increment, and (c) third load increment	135

List of Tables

Table 2.1 Damage detection steps in SHM.....	14
Table 2.2 Summary of SHM techniques; highlighted features are discussed in the below sections.....	19
Table 2.3 Machine Learning methods in SHM; the highlighted features are discussed in the below sections	31
Table 2.4 Features used in damage identification; highlighted features are discussed and used in this thesis	33
Table 2.5 Common supervised learning methods employed in SHM; highlighted parts are discussed and used in this thesis	35
Table 3.1 Maximum displacements (in m) measured from the numerical models in MATLAB (FE-M) and ABAQUS (FE-A), and the experimental model (Ex-S).....	60
Table 3.2 The summary of proposed damage cases; D, S and Sp denote displacement, strain and sporadic, respectively.	65
Table 4.1 Natural frequencies of the beam obtained from experimental tests (ExM) and FE model (FEM)	95

Abstract

Structural Health Monitoring (SHM) has emerged to offer a reliable and cost-effective solution for assessing and maintaining bridge structures within their long-term service life. Bridges are subjected to various undesirable operational and environmental loads that are prone to accelerate structural damage. For this reason, it is essential to timely assess the structural conditions to ensure safety. To this end, visual inspection and Non-destructive testing have been implemented in current practices to monitor the utmost damages. However, the disadvantages of these techniques, such as the need for prior knowledge about the damage location and being costly, time-consuming, and subjective even for skilled inspectors, emphasise the necessity of SHM techniques. This is because they can continually measure and use data obtained from structures. The practical applications of current SHM techniques in large-scale structures such as bridges, also have to deal with issues due to the inherent uncertainties of the FE modeling and damage detection processes. These include, for example modeling errors, measurement noises, uncertain operational environmental effects, and limited measurements. SHM of composite bridges is more challenging due to the complex behaviour of their steel-concrete composite (SCC) beam members. Monitoring the interfacial integrity of the SCC beams is crucial due to the shear connections governing the composite action that affects the overall response of the composite bridges. Consequently, developing innovative SHM techniques is essential to assess structural conditions and detect damage using data obtained from limited measurement points along the entire composite bridges.

In this thesis, the shortcomings mentioned above have been considered to develop novel methods for SHM applicable in composite bridges. To discover the gaps in our knowledge, the current model-based and data-driven methods used in SHM of composite bridges are reviewed, and their advantages and drawbacks are discussed. An innovative approach is developed for SHM of composite bridges with a limited number of static measurements. The method is based on an SCC beam element model, which can simulate

damage in the composite layers. The optimisation analysis is used to detect stiffness changes in the composite layers caused by damage, focusing on the composite interface.

Furthermore, a novel method for SHM of composite bridges is developed using dynamic measurements. A sensitivity-based damage detection approach is adopted with sensitive modal features from a few vibration modes. Principle component analysis is employed to reduce the input datasets and obtain an optimal model performance. Based on these features, an efficient machine learning model is developed using general regression neural networks to automate the dynamic-based damage identification of the SCC beams. The results show that the developed method can identify damage in composite structures, particularly in the interface.

In addition, a novel interlayer slip monitoring system has been developed for interfacial condition assessment of the SCC beams. The monitoring system is based on Ultra-flat Industrial Potentiometer Membrane. An experimental study has been carried out in the laboratory on a composite bridge model consisting of SCC beams. Then, the damages done to shear connectors are detected using the data obtained from the slip sensors. Results show that the possible damage locations in the composite bridges could be identified by analysing the interlayer slip in their SCC beam members. In summary, an integrated model-based and data-driven approach has been developed for composite structures using limited static and dynamic measurements in the thesis, and the results show the feasibility of the approach for condition assessment of composite bridges in practice.